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(54) **Production of three-dimensional objects**
Herstellung dreidimensionaler Objekte
Produktion d'objets tridimensionnels

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Description

The invention relates to the preparation of three-dimensional models from tomographic or CAD/CAM data wherein the models include one or more elements or portions which have a distinct colour from other elements or portions in the model or which have a distinct texture, resilience or other tactile characteristic from other elements in the model.

Several methods and apparatus have been developed for the production of three-dimensional objects or models by irradiation of compositions which crosslink and solidify upon irradiation. U.S. Patents 4,041,476 and 4,228,861 to Swainson describe the formation of three-dimensional objects by solidifying each point individually by scanning a volume point by point with intersecting beams of radiation. The Swainson methods are complex and expensive.

U.S. Patent 4,575,330 to Hull describes a method for preparing three-dimensional objects by building up successive thin layers of a solidified photopolymerizable composition. This method has become known as stereolithography. In one embodiment described in the Hull patent, a three-dimensional object is constructed by establishing a thin layer of a photocurable composition on the surface of a platform immersed in a bath of the composition and scanning the layer with a laser beam. The laser controls the X, Y dimension of the model. The Z dimension is controlled by incrementally lowering the platform to greater and greater depths after each successive layer corresponding to a cross-section of the model is polymerized or crosslinked.

WO-A-9010254 discloses a method of producing an object with differently coloured parts, by forming complete layers in baths of differently coloured photocurable compositions. The colour of every portion within the layer is the same throughout that layer.

Another method for producing three-dimensional objects is described in US Patent 4 940 412 to Blumenthal which discloses a method in which hard copy images having transparent and opaque portions are used as a mask in a photographic process to produce layers which are subsequently stacked-and attached to produce a three-dimensional object.

Models prepared previously by the foregoing process methods have been essentially homogeneous in colour and texture. The present inventors have now found a way to prepare models in which selected elements can be distinctly coloured or endowed with a distinct texture, resilience or other tactile characteristic.

In accordance with a first aspect of the present invention there is provided a method for producing a three-dimensional object, comprising the steps of:

a. providing a film of a photohardenable composition containing a photoresponsive agent,
b. forming a cross-sectional pattern of said object by irradiating said film in a pattern corresponding to the said cross-sectional pattern,
c. repeating said steps a and b to form successive adjacent cross-sectional patterns of said object, and
d. integrating said cross-sectional patterns together to provide said object,

characterized in that the object formed has selected elements which are coloured differently from other elements of said object, the method further comprising an additional step of selectively irradiating one or more portions of said cross-sectional pattern corresponding to said selected elements which are desired to be coloured differently with radiation which activates said photoresponsive agent, said photoresponsive agent thereby producing colour in or removing colour from said selected irradiated portions of said cross-sectional pattern, said additional step being carried out in between steps a and c, said step c further comprising repeating said additional step.

In a second and alternative aspect of the invention, there is provided a method for producing a three-dimensional object, comprising the steps of:

a. providing a film of a photohardenable composition,
b. forming a cross-sectional pattern of said object by irradiating said film in a pattern corresponding to the said cross-sectional pattern,
c. repeating said steps a and b to form successive adjacent cross-sectional patterns of said object, and
d. integrating said cross-sectional patterns together to provide said object,

characterized in that the object formed has selected elements which are coloured differently from other elements of said object, the method further comprising an additional step of depositing a dye on one or more portions of said cross-sectional pattern corresponding to said selected elements which are desired to be coloured differently, said additional step being carried out in between steps a and b or in between steps b and c, said step c further comprising repeating said additional step.

According to a third alternative aspect thereof, the invention provides a method for producing a three-dimensional object, the method comprising the steps of:

a. providing a film of a composition which is photohardenable,
b. forming a cross-sectional pattern of said object by irradiating said film in a pattern corresponding to the said cross-sectional pattern,
c. repeating said steps a and b to form successive adjacent cross-sectional patterns of said object, and
d. integrating said cross-sectional patterns together

to provide said object,

characterized in that the object formed has selected elements which have tactile characteristics different from those of other elements of said object, the method further comprising an additional step of altering the tactile characteristics of one or more portions of said formed cross-sectional pattern, which portion(s) correspond to said selected elements by irradiating said portion(s) with radiation to which a photoresponsive agent in said composition is responsive to cause an alteration in tactile characteristics, said additional step being carried out in between steps a and c, said step c further comprising repeating said additional step.
and

e. integrating said cross-sectional patterns together to provide said object.

Thus it will be seen that three-dimensional objects having distinctly coloured elements or elements having a distinct tactile characteristic can now readi-ly be prepared. In preferred arrangements, the three-dimensional objects are prepared by stereolithography.

In one embodiment, photoresponsive agents are incorporated into the photohardenable composition. As each lamina of the object is formed, the lamina is scanned with radiation which selectively addresses the photoresponsive agent to cause the agent to bleach, colourize, or alter the tactile characteristic of a portion of the model. Scanning to alter the colour or tactile characteristic can be conducted before, during or after the exposure which forms the lamina.

In another embodiment, a combination of photobleachable photoinitiators is used to harden the photohardenable layer. The radiation which is used to harden a preselected portion of the model is selected based upon the colour which is desired in that portion of the model. That is, by selecting a radiation which bleaches one of the photoinitiators in the photohardenable composition, the photohardenable composition will be hardened by radicals or other reactive species generated by the bleached photoinitiator while the unbleached photoinitiator colors the layer in the hardened area. In other portions of the model in which another color is desired, the photohardenable layer is hardened by exposure to radiation which bleaches another of the photoinitiators causing it to harden the layer while the remaining photoinitiator(s) color the layer.

In another embodiment, substantially colorless color formers are microencapsulated in a photodecomposable composition or they are incorporated into a photosoftenable composition and formed into microparticles. These agents are incorporated into the photohardenable composition. After or simultaneously with irradiation of the photohardenable layer, the microcapsules or microparticles are selectively irradiated at a distinct wavelength to cause them to decompose, rupture or otherwis release the contained color former. The color former reacts with the photopolymer or other agents in the composition to color the color former and hence color a portion of the model.

In still another embodiment ink jet or similar techniques are used to selectively deposit reactive or nonreactive dyes in those portions of a cross-sectional layer in which color is desired such that the dye becomes reacted into or entrapped within the layer as the layer is hardened.

The term "tactile characteristic" is used herein to mean texture, resilience, elasticity, hardness, etc.

The term "element" is used herein to mean any portion of a model such as a tumor within a model of a brain or a ligament within a model of a knee.

The term "X-Y layer" refers to a single cross-section or lamina of a three dimensional object which is individually scanned or otherwise irradiated and stacked to form a three-dimensional object.

While the invention will be particularly described with respect to its use in conjunction with stereolithography, those skilled in the art will appreciate that the teachings herein can also be used to modify other processes for producing three-dimensional objects such as those described in the aforementioned patent to Blumenthal.

Our methods will also be described with reference to processes in which the color-determinative or tactile characteristic determinative irradiation step is conducted after the cross-sectional pattern is exposed. Those skilled in the art will appreciate that the former step may be conducted before, after or simultaneously with the latter step.

In accordance with one embodiment a photochromic material is incorporated into the photohardenable composition. The photochromic material may be a photobleachable dye or a colorless dye which is colored by exposure to radiation. After scanning each X-Y layer to harden it, the layer may be scanned or otherwise irradiated to color selected areas of the layer and, hence, selected elements of the three-dimensional object when the X-Y layers are stacked. In stereolithographic processes, the layers are stacked automatically as the platform is lowered in the Z-dimension. In the Blumenthal process, the layers are stacked mechanically In the case of a photohardenable composition containing a photobleachable dye, the X-Y layer is subsequently exposed in those selected areas in which color is not desired. In the case of a photocolorable agent, those areas of the X-Y Layer in which color is desired are subsequently exposed. The photochromic agent cannot respond to the radiation which is used to harden the X-Y layer. Otherwise, the agent will be colored or bleached as the layer is hardened. Accordingly, a photochromic material is selected which is sensitive at wavelengths which are distinct from the wavelength of radiation used to harden th X-Y layer. In this manner, by subsequently irradiating those portions of the X-Y layer in which color

is desired or not desired, colored elements can be formed in the three dimensional object.

Examples of photobleachable dyes useful in the aforementioned method are well known per se and include merocyanine transformations of the benzospiropyrans described in U.S. Application Serial No. 07/649,100 filed February 1, 1991.

The aforementioned photochromic agents will be used in amounts which impart the desired color density to the model. A typical photohardenable composition may contain about .02 to 1 part of the photochromic dye per 100 parts monomer.

Examples of photocolorable dyes useful in the aforementioned method are also well known per se and include the benzospiropyrans described in U.S. Application Serial No. 07/649,100 filed February 1, 1991.

Another embodiment utilizes diazo chemistry. A photocurable X-Y layer containing a monomer, a diazo compound and a photoinitiator is irradiated with visible light to harden it in those areas corresponding to the solid areas of the three-dimensional object. After each X-Y layer is formed, those portions of the X-Y layer in which color is not desired are irradiated with ultraviolet radiation. The X-Y layer is then treated with ammonia vapor analogous to treatments used in blueprinting to selectively color the unirradiated areas.

Diazo compounds useful in this example of the method are well known per se and include those compounds used in conventional blue printing. The ammonia gas treatment can be carried out by conducting irradiation in a chamber which can be flooded with ammonia gas folloiwng exposure.

In another arrangement, microcapsules or microparticles containing colour formers or colour precursors are prepared. The walls of the microcapsules may be formed from a photodecomposable wall-forming polymer as described in Japanese patent publication 52-34488 (September 3, 1977). Alternatively, photosoftenable microparticles may be formed from photosoftenable compositions as described in U.S. Patent 4,788,125; or the color former may be microencapsulated with a photodecomposable agent that ruptures the microcapsule wall as described in Japanese Publication 44-17733 (August 4, 1969). By incorporating the color former into a photosensitive microcapsule or a photosensitive microparticle as described in the aforementioned references, a color former which would otherwise not be photoresponsive is rendered photoresponsive. By exposing the microcapsule or microparticle to actinic radiation after hardening the X-Y layer, the wall of the capsule or the particle decomposes and the color former is released. As in the case of the photochromic agents, the sensitivity of the microcapsules or microparticles must be distinct from that of the photohardenable composition such that the color precursor can be selectively released independent of the hardening of the X-Y layer.

In a more specific embodiment, the photohardenable composition may contain multiple sets of microcapsules of microparticles which individually contain different color formers. For example, three sets of microcapsules or microparticles respectively containing cyan, magenta and yellow color formers may be used to produce models having elements individually colored any number of different colors or which may be colored an authentic color. For example, microcapsules or microparticles can be prepared which will decompose or soften upon exposure to distinct bands of radiation. After hardening the X-Y layer, the cyan, magenta and yellow microcapsules or microparticles can be selectively exposed to distinct bands of radiation in selected areas of the X-Y layer in order to produce a desired color in a desired portion of the X-Y layer. For example, in those portions of the X-Y layer which are within elements in which a yellow color is desired, the layer would be exposed to radiation which decomposes the yellow color former-containing microcapsules or microparticles. This portion of the X-Y layer would not be exposed to radiation which decomposes the cyan-containing or magenta-containing microcapsules or microparticles. At the same time, in those areas of the X-Y layer corresponding to elements in which red is desired, the layer would be exposed to radiation which decomposes the magenta-containing and yellow-containing microcapsules or microparticles without exposing those areas to radiation which decomposes the cyan-containing microcapsules or microparticles.

Color formers are essentially colorless compounds. Typically they are colored by reaction with an acid or a base. Accordingly, to color the color former released from the microcapsule or microparticle, an acid or basic compound must be incorporated in the photohardenable composition. Alternatively, where the polymer formed is acid or basic, it by function as a developer for the color former.

Useful examples of color formers are well known per se and can be found in U.S. Patent 4, 399,209

In another arrangement, the photohardenable composition contains a combination of two or more photobleachable initiators. In this arrangement, the X-Y layer can be selectively coloured by subtracting out colour from the layer as the X-Y layer is formed. In this case, the X-Y layer is not uniformly exposed to the same wavelength of radiation in order to harden it. Rather, each portion of the layer is exposed to a wavelength selected based upon the colour which is desired in that particular portion of the X-Y layer. In one manifestation of this, a combination of cyan, magenta and yellow photobleachable initiators is used. These photoinitiators bleach as they initiate polymerization. In one class of photobleachable initiators, polymerization is initiated by a reductive electron transfer (Chesneau and Neckers, J. Photochem, 42, 269 (1988)) which produces the initiating radical intermediate and, in the process, the photoinitiators lose their colour.

A subtractiv color separation model for the formation of a three-dimensional object in authentic color is

thus possible. A monomer mixture containing cyan, magenta and yellow photoinitiator dyes which bleach as they form photopolymer is prepared. Their absorptions must be carefully matched such that they can be individually activated and bleached. Initiation is triggered by radiation tuned to the respective cyan, magenta or yellow absorbing wavelength. Computer input controls the wavelength, power and duration of the irradiation step to thereby control not only the formation of the X-Y layer but also the color of each portion thereof. For example, if initiation is triggered by the yellow absorbing

Examples of other reactive dyes which can be used include any dye which is modified to include a vinyl group. Examples of non-reactive dyes are readily available in the art.

From the standpoint of producing selective coloration, the composition of the photohardenable composition is not particularly critical. Examples of monomers, oligomers, and photoinitiators useful in photohardenable compositions are described in European publication No. 0 393 672 to DuPont and U.S. Patent 4,575,330, to Hull.

In a further arrangement, tactile characteristics of selected portions of the three-dimensional model are modified. In this arrangement, the degree of crosslinking is increased in selected areas of the X-Y layer to produce a tactile difference. One of the principal applications is in the preparation of three-dimensional anatomical models. It would be desirable in preparing these models to alter the tactile characteristics of certain portions of the model so as to mimic the difference touch, texture or resilience of various anatomical features. For example, in preparing a model of the knee, it would be desirable to form the bone of a highly crosslinked essentially inelastic polymer and to form the ligaments from a more elastic polymer

One technique for imparting different tactile characteristics to the model is to irradiate the X-Y layer to produce a first level of crosslinking in the polymer forming the layer. Subsequently, additional crosslinking can be introduced into selected portions of the layer by additional exposure. Alternatively, differences in the degree of crosslinking which result in different tactile characteristics may be produced by modulating the intensity of the laser beam as the X-Y layer is scanned.

One possible chemistry for use in achieving tactile differences through adjusting degree of crosslinking is based on oxime acrylates and is described in detail in Kumar, G.S., and Neckers, D.C., "Laser-induced Three Dimensional Photopolymerization Using Visible Initiators and UV Cross-Linking by Photosensitive Monomers" Macromolecules Vol. 24, No. 15, p 4322 (1991). Oxime acrylates have absorption maxima in the UV range. The paper describes a study of photopolymerization of oxime acrylates with visible initiators using an argon ion laser and photocrosslinking of pendant groups using He-Cd UV laser or a high pressure mercury vapor lamp. Thus, the X-Y layer in this embodiment may be polymerized by scanning with a visible light laser and a second scan with a UV laser can be used to modify the degree of crosslinking and to produce a tactile difference.

Claims

1. A method for producing a three-dimensional object, comprising the steps of:

   a. providing a film of a photohardenable composition containing a photoresponsive agent,
   b. forming a cross-sectional pattern of said object by irradiating said film in a pattern corresponding to the said cross-sectional pattern,
   c. repeating said steps a and b to form successive adjacent cross-sectional patterns of said object, and
   d. integrating said cross-sectional patterns together to provide said object,

   characterized in that the object formed has selected elements which are coloured differently from other elements of said object, the method further comprising an additional step of selectively irradiating one or more portions of said cross-sectional pattern corresponding to said selected elements which are desired to be coloured differently with radiation which activates said photoresponsive agent, said photoresponsive agent thereby producing colour in or removing colour from said selected irradiated portions of said cross-sectional pattern, said additional step being carried out in between steps a and c, said step c further comprising repeating said additional step.

2. A method according to Claim 1, further characterized in that said photoresponsive agent is a photobleachable dye.

3. A method according to Claim 1, further characterized in that said photoresponsive agent is a colour precursor microencapsulated in a photodecomposable wall forming polymer.

4. A method according to Claim 1, further characterized in that said photoresponsive agent is a photosoftenable microparticle containing a colour precursor.

5. A method according to any preceding claim, further characterized in that said photohardenable composition contains a plurality of photoresponsive agents, each agent controlling the formation of a different colour such that selected portions of said objects may be coloured differently.

6. A method according to any preceding claim, further characterized in that said additional step is performed after said step b.

7. A method according to any of Claims 1 to 5, further characterized in that said additional step is performed simultaneously with step b.

8. A method according to Claim 7, further characterized in that said photoresponsive agent is a photobleachable photoinitiator.

9. A method for producing a three-dimensional object, comprising the steps of:

a. providing a film of a photohardenable composition,
b. forming a cross-sectional pattern of said object by irradiating said film in a pattern corresponding to the said cross-sectional pattern,
c. repeating said steps a and b to form successive adjacent cross-sectional patterns of said object, and
d. integrating said cross-sectional patterns together to provide said object,

characterized in that the object formed has selected elements which are coloured differently from other elements of said object, the method further comprising an additional step of depositing a dye on one or more portions of said cross-sectional pattern corresponding to said selected elements which are desired to be coloured differently, said additional step being carried out in between steps a and b or in between steps b and c, said step c further comprising repeating said additional step.

10. A method according to Claim 9, further characterized in that said dye is capable of reacting with said photohardenable composition to thereby immobilize said dye in said photohardenable composition.

11. A method for producing a three-dimensional object, the method comprising the steps of:

a. providing a film of a composition which is photohardenable,
b. forming a cross-sectional pattern of said object by irradiating said film in a pattern corresponding to the said cross-sectional pattern,
c. repeating said steps a and b to form successive adjacent cross-sectional patterns of said object, and
d. integrating said cross-sectional patterns together to provide said object,

characterized in that the object formed has selected elements which have tactile characteristics different from those of other elements of said object, the method further comprising an additional step of altering the tactile characteristics of one or mor portions of said formed cross-sectional pattern, which portion(s) correspond to said selected elements by irradiating said portion(s) with radiation to which a photoresponsive agent in said composition is responsive to cause an alteration in tactile characteristics, said additional step being carried out in between steps a and c, said step c further comprising repeating said additional step.

Patentansprüche

1. Verfahren zur Herstellung eines dreidimensionalen Objektes, umfassend die folgenden Schritte:

a. Bereitstellen eines Films aus einer fotohärtbaren Zusammensetzung, die ein fotoempfindliches Mittel enthält,
b. Ausbilden einer Querschnittsstruktur des genannten Objektes durch Bestrahlen des genannten Films in einer Struktur, die der genannten Querschnittsstruktur entspricht,
c. Wiederholen der genannten Schritte a und b, um aufeinanderfolgende benachbarte Querschnittsstrukturen des genannten Objektes zu bilden, und
d. Zusammenfügen der genannten Querschnittsstrukturen zu dem genannten Objekt,

dadurch gekennzeichnet, daß das ausgebildete Objekt ausgewählte Elemente aufweist, die anders gefärbt sind als andere Elemente des genannten Objektes, wobei das Verfahren ferner einen zusätzlichen Schritt umfaßt, bei dem ein oder mehrere Teile der genannten Querschnittsstruktur, die den genannten ausgewählten Elementen entsprechen, die anders gefärbt sein sollen, selektiv mit Strahlen bestrahlt werden, die das genannte fotoempfindliche Mittel aktivieren, so daß das genannte fotoempfindliche Mittel Farbe in den genannten ausgewählten bestrahlten Teilen der genannten Querschnittsstruktur erzeugt oder daraus entfernt, wobei der genannte zusätzliche Schritt zwischen den Schritten a und c durchgeführt wird, wobei der genannte Schritt c ferner die Wiederholung des genannten zusätzlichen Schrittes umfaßt.

2. Verfahren nach Anspruch 1, ferner dadurch gekennzeichnet, daß das genannte fotoempfindliche Mittel ein fotobleichbarer Farbstoff ist.

3. Verfahren nach Anspruch 1, ferner dadurch gekennzeichnet, daß das genannte fotoempfindliche Mittel in in einem fotozersetzbaren, wandbildenden Polymer eingekapselter Farbvorläufer ist.

4. Verfahren nach Anspruch 1, ferner dadurch gekennzeichnet, daß das genannte fotoempfindliche Mittel ein fotoerweichbarer Mikropartikel ist, der einen Farbvorläufer nthält.

5. Verfahren nach einem der vorherigen Ansprüche, ferner dadurch gekennzeichnet, daß die genannte fotohärtbare Zusammensetzung eine Mehrzahl von fotoempfindlichen Mitteln enthält, wobei jedes Mittel für die Bildung einer anderen Farbe verantwortlich ist, so daß ausgewählte Teile des genannten Objektes anders gefärbt werden können.

6. Verfahren nach einem der vorherigen Ansprüche, ferner dadurch gekennzeichnet, daß der genannte zusätzliche Schritt nach dem genannten Schritt b durchgeführt wird.

7. Verfahren nach einem der Ansprüche 1 bis 5, ferner dadurch gekennzeichnet, daß der genannte zusätzliche Schritt gleichzeitig mit Schritt b durchgeführt wird.

8. Verfahren nach Anspruch 7, ferner dadurch gekennzeichnet, daß das genannte fotoempfindliche Mittel ein fotobleichbarer Fotoinitiator ist.

9. Verfahren zur Herstellung eines dreidimensionalen Objektes, umfassend die folgenden Schritte:

a. Bereitstellen eines Films aus einer fotohärtbaren Zusammensetzung,
b. Ausbilden einer Querschnittsstruktur des genannten Objektes durch Bestrahlen des genannten Films in einer Struktur, die der genannten Querschnittsstruktur entspricht,
c. Wiederholen der genannten Schritte a und b, um aufeinanderfolgende benachbarte Querschnittsstrukturen des genannten Objektes auszubilden, und
d. Zusammenfügen der genannten Querschnittsstrukturen zu dem genannten Objekt,

dadurch gekennzeichnet, daß das ausgebildete Objekt ausgewählte Elemente aufweist, die anders gefärbt sind als andere Elemente des genannten Objektes, wobei das Verfahren ferner einen zusätzlichen Schritt umfaßt, bei dem auf einen oder mehrere Teile der genannten Querschnittsstruktur, die den genannten ausgewählten Elementen entsprechen, die anders gefärbt werden sollen, ein Farbstoff aufgebracht wird, wobei der genannte zusätzliche Schritt zwischen den Schritten a und b oder zwischen den Schritten b und c durchgeführt wird, wobei der genannte Schritt c die Wiederholung des genannten zusätzlichen Schrittes umfaßt.

10. Verfahren nach Anspruch 9, ferner dadurch gekennz ichnet, daß der genannte Farbstoff mit der genannten fotohärtbaren Zusammensetzung reagieren kann, um somit den genannten Farbstoff in der genannten fotohärtbaren Zusammensetzung zu immobilisieren.

11. Verfahren zur Herstellung eines dreidimensionalen Objektes, wobei das Verfahren die folgenden Schritte umfaßt:

a. Bereitstellen eines Films aus einer Zusammensetzung, die fotohärtbar ist,
b. Ausbilden einer Querschnittsstruktur des genannten Objektes durch Bestrahlen des genannten Films in einer Struktur, die der genannten Querschnittsstruktur entspricht,
c. Wiederholen der genannten Schritte a und b, um aufeinanderfolgende benachbarte Querschnittsstrukturen des genannten Objektes auszubilden, und
d. Zusammenfügen der genannten Querschnittsstrukturen zu dem genannten Objekt,

dadurch gekennzeichnet, daß das ausgebildete Objekt ausgewählte Elemente aufweist, die andere Tastmerkmale haben als andere Elemente des genannten Objektes, wobei das Verfahren ferner einen zusätzlichen Schritt umfaßt, wobei die Tastmerkmale von einem oder mehreren Teilen der genannten ausgebildeten Querschnittsstruktur geändert werden, wobei das/die Teil/e den genannten ausgewählten Elementen entsprechen, indem das/die genannte/n Teil/e mit Strahlen bestrahlt wird/werden, auf die ein fotoempfindliches Mittel in der genannten Zusammensetzung anspricht, um eine Änderung der Tastmerkmale herbeizuführen, wobei der genannte zusätzliche Schritt zwischen den Schritten a und c durchgeführt wird, wobei der genannte Schritt c ferner die Wiederholung des genannten zusätzlichen Schritts umfaßt.

Revendications

1. Méthode de production d'un objet tridimensionnel, comprenant les étapes de :

a. mise en oeuvre d'un film d'une composition photodurcissable contenant un agent photosensible,
b. formation d'un modèle en coupe transversale dudit objet par irradiation dudit film suivant un modèle correspondant audit modèle en coupe transversale,
c. répétition desdites étapes a et b pour former des modèles en coupe transversale adjacents successifs dudit objet, et
d. intégration mutuelle desdits modèles en cou-

pe transversale pour fournir ledit objet,

caractérisée en ce que l'objet formé a des éléments sélectionnés qui sont colorés différemment des autres éléments dudit objet, la méthode comprenant en outre une étape supplémentaire d'irradiation sélective d'une ou plusieurs parties dudit modèle en coupe transversale correspondant auxdits éléments sélectionnés que l'on veut colorer différemment avec un rayonnement qui active ledit agent photosensible, ledit agent photosensible produisant ainsi une couleur ou enlevant une couleur dans lesdites parties irradiées choisies dudit modèle en coupe transversale, ladite étape supplémentaire étant mise en oeuvre entre les étapes a et c, ladite étape c comprenant en outre la répétition de ladite étape supplémentaire.

2. Méthode selon la Revendication 1, caractérisée en outre en ce que ledit agent photosensible est un colorant photodécolorable.

3. Méthode selon la Revendication 1, caractérisée en outre en ce que ledit agent photosensible est un précurseur de couleur microencapsulé dans un polymère formant une paroi photodécomposable.

4. Méthode selon la Revendication 1, caractérisée en outre en ce que ledit agent photosensible est une microparticule photoramollissable contenant un précurseur de couleur.

5. Méthode selon l'une quelconque des revendications précédentes, caractérisée en outre en ce que ladite composition photodurcissable contient plusieurs agents photosensibles, chaque agent contrôlant la formation d'une couleur différente de telle sorte que des parties sélectionnées desdits objets peuvent être colorées différemment.

6. Méthode selon l'une quelconque des revendications précédentes, caractérisée en outre en ce que ladite étape supplémentaire est mise en oeuvre après ladite étape b.

7. Méthode selon l'une quelconque des Revendications 1 à 5, caractérisée en outre en ce que ladite étape supplémentaire est mise en oeuvre en même temps que l'étape b.

8. Méthode selon la Revendication 7, caractérisée en outre en ce que ledit agent photosensible est un photoamorceur photodécolorable.

9. Méthode de production d'un objet tridimensionnel, comprenant les étapes de :

a. mise en oeuvre d'un film d'une composition photodurcissable,
b. formation d'un modèle en coupe transversale dudit objet par irradiation dudit film suivant un modèle correspondant audit modèle n coupe transversale,
c. répétition desdites étapes a et b pour former des modèles en coupe transversale adjacents successifs dudit objet, et
d. intégration mutuelle desdits modèles en coupe transversale pour fournir ledit objet,

caractérisée en ce que l'objet formé a des éléments sélectionnés qui sont colorés différemment des autres éléments dudit objet, la méthode comprenant en outre une étape supplémentaire de dépôt d'un colorant sur une ou plusieurs parties dudit modèle en coupe transversale correspondant auxdits éléments sélectionnés que l'on veut colorer différemment, ladite étape supplémentaire étant mise en oeuvre entre les étapes a et b ou entre les étapes b et c, ladite étape c comprenant en outre la répétition de ladite étape supplémentaire.

10. Méthode selon la Revendication 9, caractérisée en outre en ce que ledit colorant est capable de réagir avec ladite composition photodurcissable pour immobiliser ainsi ledit colorant dans ladite composition photodurcissable.

11. Méthode de production d'un objet tridimensionnel, la méthode comprenant les étapes de :

a. mise en oeuvre d'un film d'une composition qui est photodurcissable,
b. formation d'un modèle en coupe transversale dudit objet par irradiation dudit film suivant un modèle correspondant audit modèle en coupe transversale,
c. répétition desdites étapes a et b pour former des modèles en coupe transversale adjacents successifs dudit objet, et
d. intégration mutuelle desdits modèles en coupe transversale pour fournir ledit objet,

caractérisée en ce que l'objet formé a des éléments sélectionnés qui ont des caractéristiques tactiles différentes de celles d'autres éléments dudit objet, la méthode comprenant en outre une étape supplémentaire de modification des caractéristiques tactiles d'une ou plusieurs parties dudit modèle en coupe transversale formé, la ou lesdites parties correspondant auxdits éléments sélectionnés, par irradiation de la ou desdites parties avec un rayonnement auquel un agent photosensible contenu dans ladite composition est sensible pour provoquer une modification des caractéristiques tactiles, ladite étape supplémentaire étant mise en oeuvre entre les étapes a et c, ladite étape c com-

prenant en outre la répétition de ladite étape supplémentaire.